Shock Mitigation for High Speed Planing Boats

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Document #: N0001400WX20018
http://www.onr.navy.mil/sci_tech/ocean/onrpgahb.htm

LONG-TERM GOAL

Boat operators and crew of U.S. Naval Special Warfare (NSW) high speed planing boats (HSPB) experience fatigue, loss in performance and acute and long-term injuries produced by years of repeated severe boat-wave impacts. The long-term goal for this effort is to investigate means for mitigating these impact loads to the human. The primary components of this goal are: 1) to investigate technologies that mitigate the injurious shock imparted to the operators without decreasing boat performance, and 2) to further develop planing boat theory for future development of shock mitigation technologies. This dual-use research is applicable to Navy and other Department of Defense (DoD) small boat operations, as well as private-sector commercial and pleasure boat markets.

OBJECTIVES

The overall technical objectives of the CSS shock mitigation research are to better understand the complexities of the impact between the hull and water through simultaneous theoretical and experimental work, and then to apply this understanding to tools for developing shock mitigation methods. For the past several years, CSS has been working with the University of Michigan (UM) and the ONR-directed Gulf Coast Region Maritime Technology Center (GCRMTC) at the University of New Orleans (UNO) to achieve these long-term objectives. During FY00, focus was placed on the indentifaction of shock mitigating seating technologies which could be retrofitted on existing Special Operations Forces (SOF) craft. There were three objectives for the shock mitigation task:

- To identify shock mitigation methods/technologies that can be applied to high speed boat seats and bolsters. It is anticipated that different techniques may be required for different craft. In addition, the boat operators have different shock mitigating requirements than passengers.
- To evaluate technologies showing promise to mitigate the injurious impacts of high-speed planing boats.
- To coordinate with the United States Special Operations Command (USSOCOM) to develop quantified shock mitigation requirements and specifications that can be applied to planing boat research and development.

APPROACH

The approach taken to identify seat/bolster technologies which may have potential to mitigate shock on high speed planing boats consisted of 1) the development of a set of requirements for seat/bolster shock mitigation, 2) the identification of emerging technoloogies that could be appliced to seats/bolsters and 3) the assessment through modeling and testing of promising concepts.

Working closely with USSOCOM, existing shock data and requirements were reviewed. A preliminary requirements document was then developed.

A *Commerce Business Daily (CBD)* announcement looking for seating/bolster shock mitigation concepts was issued. Information and proposals were received and reviewed. The most promisting options were identified.

Analysis was performed for a passive seat suspension system. The impact-modeling program WEDIM was used to model the impact of a Mk V SOC with different passive seat suspension designs. The program, which has been successfully used to model drop test impacts, was modified to extend its capabilities to cover this analysis.

Two seating concept prototypes are being obtained for testing first quarter FY01. Side-by-side experiments will be performed with a conventional rigid seat. The goal of the test is to obtain initial quantitative data, with minimum expenditure, to determine if further expenditure and investigation is warranted.

Testing will be performed on an actual high speed planing craft. Both the boat and the humans will be instrumented. Another important although qualitative measurement will be operator feedback. Additionally, a video camera would be mounted on the console to record relative operator motions and reactions during impacts. The instrumented boat will be run numerous times across a large boat wake to produce discrete impact events that will be measured with accelerometers and analyzed. The results of the testing along with recommendations will be documented.

WORK COMPLETED

The work completed included coordination with USSOCOM to develop requirements, generation of a CBD announcement and calls for information for shock mitigation methods applicable to high speed boat seats and bolsters, evaluation of the responses and analysis of options and design parameters.

Four techniques for seat shock mitigation, both active and passive, were identified that show promise in reducing shock on high speed boats. Table 1 includes the four techniques, the proposing vendors, and some brief information on each.

Table 1. Techniques Showing Promise for Shock Mitigation

TECHNIQUE	VENDOR
Acceleration dependent damping shock absorbers: Use an Inertial Active System (IAS) which changes the damping ratio in response to accelerations instead of velocity as in standard dampers.	Edelbrock/RICOR
Electric actuator based on helicopter rescue hoist: Use A Mechanical-To-Thermal Energy Transfer (METET) device to absorb shock loads of 4g or greater. The METET device is a mechanism, which operates on visco-elastic theory to provide energy absorption due to interface shear damping.	FFF Engineering
Integrated suspended seat: Dr. Johan Ullman of the Ullman Human Design Group, Goteburg, Sweden has developed and built a cockpit system which includes 1) a seat with backrest and foam padding and a passive spring/damper isolation component, 2) foot rests, and 3) handlebars with controls on the handles. While the Ullman Cockpit appears unconventional relative to traditional US military cockpit/seat designs, the system holds promise for substantial reduction of discomfort and injury. Further, the passive components avoid the introduction of expensive, heavy, and complex active electro-mechanical isolator components. Finally, the incorporation of boat controls within the handlebar is expected to improve the operator's ability to control the boat in rough sea conditions.	Ullman Design Group
Adaptation of fully active land vehicle suspension: The University of Texas at Austin Center for Electromechanics proposes to design an active system to reduce shock loading on crew members by a factor of 30 to 40 compared to current non-suspended seats and up to 10 compared to passively suspended seats. It will consist of electromechanical actuator(s) mechanically in parallel with passive spring(s), accelerometer(s), and control system and power electronics. This work will build on approximately $4.5M of technology developed for active electromechanical suspension systems for off road vehicles. This seating concept is expected to provide the most shock mitigation, but also may be the most expensive and complex to implement on NSW boats.	University of Texas

The impact-modeling program WEDIM was modified to model the impact of a Mk V SOC with different passive seat suspension designs. Data from a Mk V SOC motion test[2] were used to determine the magnitude of the impact to model. The WEDIM code was used to determine the shape of the impact's acceleration profile and to analyze the seat dynamics. The suspension modeling capabilities were enhanced to model non-linear springs with preload and non-linear dampers with different responses in compression and rebound. In addition, an inertial damping function was included to model a promising suspension damper, the Inertial Active System (IAS). The IAS system consists of a mass and a spring on the damper piston that opens an orifice to soften the suspension in response to accelerations. Through this modeling, CSS has developed specifications for an IAS shock absorber, which will be provided to Edelbrock/RICOR who will fabricate a prototype for integration into a seat, testing and evaluation.

RESULTS

The WEDIM seat suspension analysis resulted in the design of a seat suspension that reduces a 10g boat impact to approximately 5 g. The 10g impact loading represents the peak loading on a seated occupant in the Mk V SOC's CIC. This location experienced the highest loading of any location used during high-speed transits. Figure 1 shows the seat suspension response to the impact. The IAS damper allows the seat to remain relatively fixed because of the stiff damping at low accelerations. When a g-loading threshold of 4g is reached, the IAS opens and the suspension stiffness is dramatically reduced. This allows the seat suspension to deflect quickly to absorb the impact. Seat deflection was limited to 7 inches.

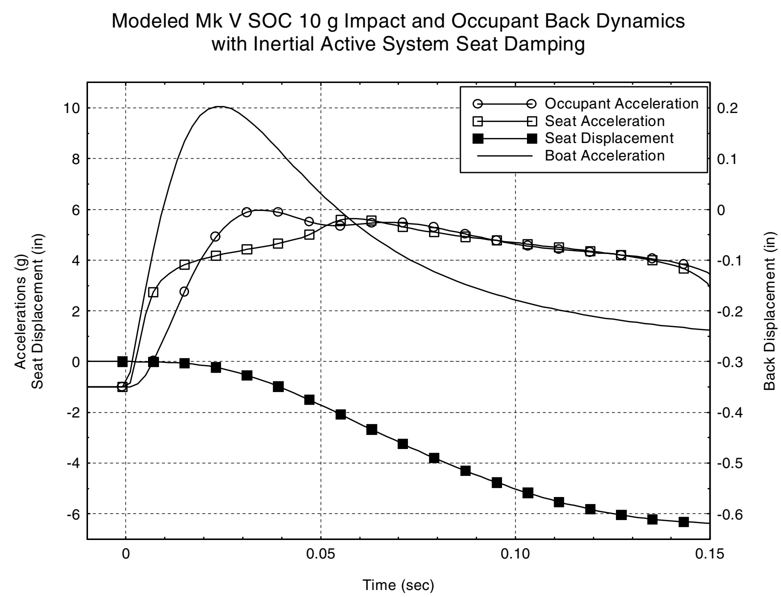

Figure 1 Shows the Seat Suspension Response to the Impact.

The injury response of this suspension is also positive. For the baseline Mk V SOC impact with no seat suspension, the Displacement Response Index (DRI) is 13. The DRI considers the dynamics of the human back and is a measure of how much spinal compression is allowable before injury occurs. The low-risk threshold for this impact is 15. On the Glaister curve for a seated person, the baseline impact is 40 percent above what is considered injurious. The Glaister curves represent the acceleration loading that will produce injury for a square acceleration pulse. The definition of the curves using a square pulse means that the pulse width here has to be estimated. However, it does remain a valuable tool for determining relative improvements in impact loading

With the IAS suspension, the DRI was reduced to 6.5, thus putting the occupant at very low risk for injury. Using the Glaister curve, the impact was considered to be 10 percent over that which would produce an injury.

IMPACT/APPLICATION

The development of a passive seat suspension design shows a potential for a low-cost seat suspension system that could help reduce the injuries to high-speed planing boat operators and occupants. This suspension has the potential for dual-use in the recreational boating market.

Other concepts have been identified with potential to mitigate damaging impact forces on high speed craft. These concepts can be improved in conjunction with the CSS WEDIM simulation and evaluation for application to existing and future NSW planing boats.

TRANSITIONS

The work performed under this program was coordinated closely with United States Special Operations Command to facilitate transition into a USSOCOM shock mitigation program in FY01.

RELATED PROJECTS

Dr. Vorus of UNO is the principal investigator of the GCRMTC project "Shock Reduction for High Speed Planing Boats." Doctoral student Richard Royce from UNO also participates in the research, as does Dr. Troesch of UM.

Mr. Graeme Finch of Industrial Research Limited in New Zealand has also been performing small-boat motion tests with an emphasis on comfort and motion sickness research.

REFERENCES

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PUBLICATIONS

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